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The effects of inquiry-based learning on elementary students' conceptual understanding of matter, scientific process skills and science attitudes

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Abstract

The present study aimed to investigate the effects of Inquiry-Based Learning (IBL) environments, on students' conceptual understanding of matter, scientific process skills and attitudes towards science. A teaching intervention was designed on the basis of IBL principles, which was put into practice in a 5th grade science class (n=20). Instruction lasted 8 weeks in total as provided by normal science curriculum. The success of teaching intervention was tested via concept test, scientific process skills test and attitude scale. The findings indicated that IBL had a positive impact on students' conceptual understanding and scientific process skills, but did not make any difference on their attitudes towards science.

Keywords: inquiry-based learning; scientific process skills; conceptual understanding; matter.

1. Introduction

Having accepted the constructivist philosophy in education, starting from 2005 in Turkey, the primary aim of the instruction has become helping students acquire skills rather than gain scientific knowledge (MEB, 2005). As a logical consequence of this change, science learning has been viewed as construction of scientific knowledge by the learner via observation and experimentation. Thus, the metaphor "students as scientist" (Driver, 1985) come to the fore with its main emphasis on scientific process skills. In this line, teaching methods shifted from lecture-based towards student-centred approaches. The traditional Turkish teaching has therefore become constructivist in a sense that students are provided opportunity to carry out investigations to test their ideas and construct their own knowledge, making inquiries as little scientists. Yet, on examination of the new primary science programme, instructional activities appear do not support inquiry-based learning where students can make their own inquiries. Experiments included in the programme are generally in recipe form on which the procedure needs to be followed is written. Having acknowledged the importance of this type of laboratory work, we think that inquiry based learning

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(IBL) approaches might be more effective in helping students to acquire scientific process skills. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and share their ideas with others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills (NRC, 1996). Scientific experiments are, by nature, inquiry-based activities; students must learn to propose hypotheses, design experiments, and select appropriate materials (Correiro, Griffin & Hart, 2008). All of these activities will certainly contribute to not only students' scientific inquiry skills but also their understanding of science concepts. Hofstein & Lunetta (2004) add to this list by emphasizing the central role played by the science laboratory in contributing to students' perception of science and attitudes by stimulating interest and enjoyment, and motivating students to learn science.

Research on effectiveness of IBL on students' learning, indicated improvement in students' understandings (Wu & Krajcik, 2006; Fortus, et al. 2004; Marx, et al. 2004; Wallace, Tsoi, Calkin, & Darley, 2003) and in their process skills (Wu & Hsieh, 2006; Tatar, 2006; Sullivan, 2008). There is indication that students' attitudes towards science are improved after having involved in IBL environments (Gibson & Chase, 2002). There are studies that investigate the effects of inquiry-based learning environments over fifth grade students' understanding and scientific process skills (Stout, 2001; Martin-Hansen, 2005; Schwartz, 2007; Lindquist, 2001). However, they focused on conducting IBL on specific topics such as crayfish (Martin-Hansen, 2005), energy transfers (Schwartz, 2007), autumnal seasonal change (Lindquist, 2001) and water cycle & weather (Stout, 2001) rather than designing an inquiry-based teaching intervention on a whole curriculum unit such as matter. This study was therefore designed in order that a teaching intervention based on IBL strategies could be developed and evaluated with the aims of promoting conceptual understanding of matter and scientific process skills.

2. Method

2.1. Rationale for the teaching intervention

One of the principles informing the design of the teaching intervention relates to insights gained by other researchers who have investigated inquiry-based learning (IBL). We reviewed the literature on IBL with special focus on its effectiveness in promoting conceptual understanding. Findings from previous studies were drawn upon in deciding the type of IBL and designing problems to be searched during teaching. Another principle drawn on to inform the design of the teaching involves socio-cultural constructivist perspective (Vygotsky, 1978). This perspective was benefited in structuring the pedagogy that the teacher will adopt during teaching intervention. Within this model of teaching, the teacher uses language to shape, select and emphasise the ideas offered by the class in order to create the shared meaning. In the line of this perspective, the teaching intervention was designed to encourage students to verbalise their ideas and comments on the ideas of others while carry out the inquiry. Finally, the previous research findings on students' understandings on matter (Barker, 2000; Smith, Wiser, Anderson, & Krajcik, 2006) were reviewed so as to find out conceptual difficulties experienced by students. These were drawn upon in determining the learning goals of the teaching intervention and the instructional activities.

2.2. Research Design and Methodology

The study was conducted in a private elementary school in Istanbul. The teaching intervention was put into practice in a 5th grade class whose students' aged 10–11 (n = 20; 11 boys, 9 girls). The teaching intervention (IBL) lasted 8 weeks in total as provided by existing science curriculum. One of us (P.Ş) who is science teacher of the school implemented the teaching intervention. It was carried out in the science laboratory. Throughout the teaching intervention, students worked in small groups where they were encouraged to share their ideas with their classmates, discuss their observations and interpret findings of the experiments carried out.

Students completed the same data collection instruments before and after instruction so that changes in their conceptual understanding, scientific process skills and science attitudes can be spotted. These were concept test, scientific process skills test and science attitude scale. The effectiveness of the teaching intervention was therefore tested via these three instruments. The concept test was designed by the authors. It was designed to assess students' understandings about 'matter'. The test included 38 multiple choice questions at the outset. After piloting and reliability analyses, 11 questions were discarded from the original test. The reliability (cronbach alfa coefficient) was found as 0.857. So as to determine students' scientific skills, scientific process skill test translated in Turkish by Koray, Köksal, Özdemir & Presley (2007). It included 31 items, all of which were multiple choice questions. The Kuder-Richardson-21 reliability coefficient was estimated as 0.81. In determination of students' attitudes towards science, science attitude scale developed by Akınoğlu (2001) was benefited. The test included 20 items and it was a 5-point Likert scale, which ranged from strongly disagree to strongly agree. The reliability coefficient (cronbach alfa coefficient) was found as 0.89.

Data obtained via the instruments mentioned above were analysed with SPSS 16.0 program. Mean and standard deviations of the test scores were calculated. It was observed that the scores are distributed normally. Therefore, the paired-samples T test was conducted to figure out whether there is a significant difference between the pre and post-tests scores of the students involved in the study.

3. Findings

The effectiveness of the teaching intervention was approached from three different angles. These were conceptual understanding, process skills and attitudes towards science. In the first of these, effectiveness of IBL teaching was taken to mean helping students to produce correct answers to the concept test. Secondly, it was taken to mean contributing students' conceptual understanding by remedying their misconceptions prior to the teaching intervention. As regards of the effectiveness of IBL on students' process skills and attitudes, the term effectiveness is taken to mean obtaining high scores in the two instruments aforementioned.

3.1. Effectiveness of IBL on students' conceptual understanding

As previously stated, concept test about matter were used to assess students' conceptual understanding. At the outset of the analysis, students' responses to questions were examined and scored. The paired-samples T test was used to compare the change in the means of pre and post concept test scores of the students. The results of the analysis of students' responses to concept test prior to and after the teaching intervention are presented in Table 1.

Table 1. The paired samples T test results concerning the concept test scores of the students

Tests	N	Mean	Std. Deviation	df	T	p
Pre-Test	20	9.50	3.692	19	-7.282	0.000
Post-Test	20	18.55	5.978			

Table 1 shows that there is a significant difference in students' pre-test and post-test concept scores [$t(19)= -7.282$; $p<.05$]. The difference is in favor of students' post-test scores. The arithmetic average of students' concept test scores was 9.50 before the teaching intervention. This mean was increased to 18.55 after the instruction. This indicates that inquiry-based learning has a positive impact on students' conceptual understanding. Students' responses to concept test were also examined in terms of the change in their misconceptions. In the line of this analysis, it is possible to say that the teaching intervention remedies most of the pre-instructional misconceptions, albeit in differential ratios. Due to space constraints the results of this analysis specifically carried out for each question were not reported in the present paper.

3.2. Effectiveness of IBL on students' scientific process skills

Effectiveness of the teaching intervention on the students' process skills was decided on the base of the scores they obtained from scientific process skills test. Thus, the students' scores obtained from the scientific process skills test before and after the inquiry-based teaching were determined. The paired-samples T test results concerning the pre and post-test scores are listed in Table 2.

Table 2. The paired samples T test results concerning the scientific process skill test scores of the students

Tests	N	Mean	Std. Deviation	df	T	P
Pre-Test	20	13.50	3.487	19	-2.742	0.013
Post-Test	20	17.00	4.963			

According to Table 2, there is a significant difference in students' pre and post-test scientific process skills in favor of the post-test scores [t(19) = - 2,742; p<.05]. Prior to the teaching intervention, the mean of the students' scientific process skills score was 13.50. This number was raised to 17.00 after the teaching intervention. This change supports the claim that the students' scientific process skills improved after involving inquiry-based learning activities. Upon examination of the students' sub-scientific process skill scores prior to and after the teaching intervention, it became clear that the students' sub-process skills were improved. However, the greatest improvements were detected especially in the students' measurement skills, correlation/classification skills and forming hypothesis. The pre and post-test scores for these sub-process skills were increased from 23 to 35, 27 to 40 and 13 to 30 respectively.

3.3. Effectiveness of IBL on students' attitudes towards science

The teaching intervention was not designed specifically to contribute to students' attitudes towards science. Yet, it was assumed that it might have a positive effect over the students' attitudes as they were free to choice what to investigate, use their own method to follow and conduct the investigation on their own pace. Whether this was the case is the question that motivates finding out the effectiveness of IBL over students' attitudes. In this respect, the students' attitudes towards science were scored prior to and after the teaching intervention. The result of the paired-samples T test conducted to find out difference between pre and post attitude scores are presented in Table 3.

Table 3. The paired samples T test results concerning the attitude scale scores of the students

Tests	N	Mean	Std. Deviation	Df	T	P
Pre-Test	20	87.05	12.939	19	0.435	0.669
Post-Test	20	86.35	13.546			

It is clear from Table 3 that there is not a significant change in students' pre and post science attitude scores [t(19) = 0.435, p > .05]. This result indicates that the inquiry-based teaching did not make any significant effect over the students' attitudes towards science.

4. Conclusion and Recommendation

Inquiry is defined as a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts (NRC, 1996). Educators assert that knowledge is enhanced when students are actively engaged in the learning process and when this is coupled with guidance and scaffolding from the instructor, students are able to gain a better understanding of science concepts (Correiro, Griffin & Hart, 2008; Martin-Hansen, 2005; Lindquist, 2001). The present study provided empirical evidence to this assertion by producing research data that shows IBL improved students' conceptual understanding. On quantitative grounds, it was found that scientifically acceptable responses provided by students were increased after having involved in IBL activities. In qualitative sense, it is possible to say that pre instructional misconceptions concerning matter either were decreased or diminished after the teaching intervention.

Inquiry involves posing questions, searching for explanations, testing these explanations and producing knowledge. In other words, students use scientific process skills during inquiry. Thus, it is expected that inquiry-based teaching develops students' scientific process skills as it was found in the present study. This finding is parallel to the previous research findings (Stout, 2001; Tatar, 2006; Wu & Hsieh, 2006; Sullivan, 2008). On the other hand, the teaching intervention designed did not have an impact on students' attitudes towards science. This might stem from different reasons. It might be that the IBL does not cause change in science attitudes. If this is the case then this finding both contradicts with (Gibson & Chase, 2002) and is parallel to (Lindquist, 2001) the existing research. On the other hand, it might be that 8 week teaching time was not enough in changing students' attitudes towards science. This finding is also parallel to the results of the previous studies as research on attitudes indicates that attitude towards science does not change over a short period of time (Neiderhauser, 1994; Ünal & Ergin, 2006). It might well be that both contributed on this. Unfortunately, it is difficult to know this in the line of the findings provided by the present study.

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